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TWO-NEUTRON TRANSFER IN Pt AND Os NUCLEI AND THE IBA*

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ABSTRACT

Two-neutron transfer studies in Pt and Os were investigated. The extracted relative enhancement factors in Pt were found to be in excellent agreement with the O(5) limit predictions. The differences in transfer strength between Pt and Os (t,p) could not be reproduced within the present framework of the Interacting Boson Approximation Model.

EXPERIMENTAL ANALYSIS

To test the predictions of the Interacting Boson Approximation¹ (IBA) model of Arima and Iachello, we have recently investigated² the Pt, Os(t,p) reactions at $E_t=17$ MeV. Given the positive ground-state Q-values for these reactions, the reaction protons are being emitted well above the Coulomb barrier, making it possible to extract relatively reliable nuclear spectroscopic strengths.

The enhancement factors ϵ given by

$$\sigma_{\text{exp}} = \epsilon N \sigma_{\text{DW}} \quad (1)$$

were obtained² from distorted wave calculations using standard optical model parameters. In extracting spectroscopic information from our (t,p) measurements, we have assumed a simple one-step DWBA mechanism for the (t,p) reaction, neglecting the effects due to inelastic scattering combined with two-neutron transfer or sequential transfer. Neglecting

coupled-channel effects in this mass region should be reasonable when one restricts the investigation to the dominant ground-state to ground-state transitions. Because coupled-channel effects will be more important for excited states, we have not investigated $L=2$ transitions and will only briefly discuss excited $L=0$ transitions.

Another simplification in our analysis is the use of the same $(2p_{3/2})^2$ form factor in our DWBA calculations. Because the IBA deals with collective excitations, it was felt a more microscopic form factor, with several components which varied from nucleus to nucleus as the single particle structure near the Fermi surface changed, would be inappropriate for an initial comparison of IBA predicted and empirical two-neutron transfer strengths. For this reason it may be more accurate to call our ϵ -values experimental cross sections from which Q -value and A dependences have been removed.

TWO-NEUTRON TRANSFER STRENGTHS

In order to calculate two-neutron transfer strengths within the IBA model, Arima and Michello have chosen to define the $L=0$ two-neutron transfer operators³ as essentially neutron s -boson creation and annihilation operators that properly account for the finite dimensionality of the boson space. In the limiting symmetries of the IBA-1 model (which does not distinguish between neutron and proton degrees of freedom) they obtained the following analytical expressions for the ground-state to ground-state transition strengths^{1,3}

$$1^{SU(5)}(N_\nu \rightarrow N_\nu + 1) = \alpha_\nu^2 (N_\nu + 1)(\Omega_\nu - N_\nu) \quad (2)$$

$$1^{SU(3)}(N_\nu \rightarrow N_\nu + 1) = \alpha_\nu^2 (N_\nu + 1) \left(\frac{2N_\nu + 3}{3(2N_\nu + 1)} \right) \left(\Omega_\nu - N_\nu - \frac{4(N_\nu - 1)N_\nu}{3(2N_\nu - 1)} \right) \quad (3)$$

$$1^{O(6)}(N_\nu \rightarrow N_\nu + 1) = \alpha_\nu^2 \frac{(N_\nu + 1)(N_\nu + 1)}{2(N_\nu + 2)} \left(\Omega_\nu - N_\nu - \frac{(N_\nu - 1)N_\nu}{2(N_\nu + 1)} \right) \quad (4)$$

Here N_ν is the total number of neutron bosons, N is the total number of bosons, and Ω_ν is the boson degeneracy of the shell (for the 82-126 interval $\Omega_\nu = 22$). The strength of the operator is incorporated in α_ν^2 . In addition to the analytical expressions, there are selection rules which help determine the allowed transitions to excited 0^+ states. These are illustrated by the arrows in Fig. 1. One sees that transitions to excited states are forbidden in the $SU(5)$ limit, while one excited 0^+ state will be populated in (t, p) reactions (at beginning of shell) in the $SU(3)$ and $O(6)$

Fig. 1. Selection rules for two-particle transfer in IBA limits.

Fig. 2. Relative Pt, Os ϵ -values and IBA limit predictions.

limits. (For the Pt and Os nuclei where the bosons are "hole" bosons the roles of the (n, p) and (p, t) reactions are reversed.) In addition to the analytical expressions, the IBA-1 Hamiltonian may be solved⁴ for intermediate structures and the two-neutron transfer strengths obtained numerically.

The ground-state relative ϵ -values for Pt, Os (t, p) are summarized in Fig. 2. We have included the values from a 35 MeV Pt (p, t) measurement⁵ by Deason and co-workers. The Pt empirical values are normalized to the ^{194}Pt - ^{196}Pt ground-state transitions. For the Pt (t, p) reaction the predictions of the O(6) limit of the IBA are in excellent agreement with the empirical relative ϵ -values; the SU(5) predictions deviate markedly from the empirical strengths. The Pt (t, p) values were extracted from measurements on natural targets, hence minimizing the experimental errors in extracting ϵ -values. However, the Pt (p, t) measurements were only performed on enriched targets and the $^{196}\text{Pt}(p, t)^{194}\text{Pt}$ ϵ -value, to which theory and data were normalized, appears to be low, indicating that the available Pt (p, t) measurement may be inadequate for our purposes.

The relative two-neutron transfer strengths in Os normalized to the ^{190}Os - ^{192}Os g. s. value are fairly insensitive to the structure of these nuclei, with the SU(3), O(6) and any intermediate structure giving essentially identical results. Also, the transfer strengths to excited 0^+ states are not a sensitive probe of the IBA predictions since the allowed transitions illustrated in Fig. 1 are predicted to be $\sim 8-10\%$ of the ground-state strength while most 0^+ states will be populated with 2-3% of the ground-state strength due to two quasi-particle admixtures in the wave functions. This is in contrast to absolute and relative B(E2) values associated with excited 0^+ states where orders of magnitude differences are observed between allowed and forbidden transition strengths.

Instead of examining relative ϵ -values within one element, we have also obtained ϵ -values to compare Pt and Os (t, p) strengths to each other, as summarized in Fig. 3. Again, the empirical and O(6) predicted strengths are normalized to the $^{194}\text{Pt}(t, p)^{196}\text{Pt}$ ground-state transition, effectively obtaining the α_V^2 parameter in eq. 2-4. Although, as seen in Fig. 2, there is excellent agreement between the IBA-1 O(6) limit predictions and the Pt ϵ -values, there is a marked discrepancy between the values expected from the O(6) and SU(3) predictions and the ϵ -values obtained for Os (t, p) . Recently, a numerical solution based on an IBA-1 O(6) $\rightarrow$ SU(3) transition⁶ in the Pt-Os nuclei was investigated and found to be in excellent agreement with the γ -ray transition probabilities in these nuclei. While the two-neutron transfer strength predictions using the parameters of Ref. 6 are essentially identical to the O(6) limit predictions in Pt and do predict two-neutron

transfer strengths intermediate between the $O(6)$ and $SU(3)$ limit values for Os, these calculations are also in marked disagreement with the Os empirical ϵ -values. Recent IBA-2 calculations⁷ in which the neutron and proton degrees of freedom are explicitly included, and, hence, should provide a more accurate test of two-neutron transfer strengths than the one-boson IBA-1 model, have been performed. Despite the excellent agreement Bijker and co-workers obtained for the other properties of the Pt-Os nuclei, they fail to reproduce the differences between Pt and Os ground-state transfer strengths.

The inadequacy of the IBA to reproduce two-neutron "absolute" strengths may be due to several effects. Possibly the method used to extract the ϵ -values in Fig. 3 does not correspond to an "absolute" strength and is simply a measure of Q -reduced cross sections and, therefore, the comparison between Pt and Os in Fig. 3 is meaningless. If one assumes the method is reasonable, then one is left with an inadequacy of the IBA model as investigated so far to understand two-particle transfer. It is well known that certain single-particle orbitals such as $p_{3/2}$ give large (t,p) and (p,t) cross sections. If the relative location of the Fermi surfaces in Pt and Os are such that Pt is closer to the "hot orbitals" while Os is further

Fig. 3. Comparison between Pt, Os ϵ -values and IBA.

away, one would expect the Pt ϵ -values to be larger than those in Os. Since the IBA-1 and IBA-2 models only deal with the collectivity of the g. s. wave functions and the single-particle components of the bosons are not available, maybe it is unrealistic to expect the IBA to reproduce all trends in two-neutron transfer strengths. However, the success the IBA has in reproducing relative ϵ -values, especially in Pt, may indicate that the importance of particular orbitals is less critical for a given isotope chain and, therefore, it is valid to compare IBA predictions to relative ϵ -values for each element.

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